



Five-year clinic-based period proportion, demographic profile, and clinical characteristics of recorded keratoconus at tertiary eye centers

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ABSTRACT

Background: Keratoconus (KC) is a progressive, asymmetric, usually bilateral disorder characterized by central or paracentral corneal thinning. Epidemiological data from the United Arab Emirates (UAE) remain limited. This study estimated the five-year clinic-based period proportion of attendees with recorded KC and described their demographic and clinical characteristics at UAE tertiary eye centers.

Methods: Retrospective cross-sectional study including unique patients aged ≥ 10 years at their first eligible encounter who attended Magrabi Health Centers in Abu Dhabi, Al Ain, or Dubai between January 2020 and December 2024. Unique clinic attendees were identified from electronic medical records; KC cases were identified using a prespecified set of recorded keratoconus diagnosis codes within the ICD-10-CM H18.6 category. Universal systematic KC screening was not conducted for all attendees. The clinical records of KC cases were reviewed for demographic and ocular characteristics. Severity was categorized using a study-specific composite classification informed by selected Amsler–Krumeich and Belin ABCD criteria and based on available keratometric, refractive, pachymetric, and corneal-scarring data.

Results: Among 15,431 unique clinic attendees, 1,027 had recorded KC, corresponding to a five-year clinic-based period proportion of 6.66% (95% CI, 6.27% to 7.06%). The proportion differed significantly by age group, sex, nationality, and location (all $P < 0.001$). The highest age-specific proportion was observed among the 21–30 age group (14.07%), followed by the 31–40 age group (13.49%). In the exploratory adjusted analysis, compared to attendees aged ≤ 20 years the 21–30 age group had the highest adjusted odds ratio (aOR) for recorded KC (aOR = 4.15; 95% CI, 3.34 to 5.15), followed by the 31–40 age group (aOR = 3.85; 95% CI, 3.10 to 4.79). Males (aOR = 1.62; 95% CI, 1.40 to 1.86) and non-Emiratis (aOR = 1.86; 95% CI, 1.63 to 2.13) also had higher adjusted odds of recorded KC. Compared with attendees in Abu Dhabi, those in Al Ain (aOR = 0.46; 95% CI, 0.35 to 0.60) and Dubai (aOR = 0.28; 95% CI, 0.23 to 0.34) had lower adjusted odds. Bilateral involvement occurred in 77.9% (800/1,027) of KC cases. Category I was the most frequent study-specific composite severity category among affected right eyes (54.2%; 499/921) and left eyes (56.8%; 515/906). Corneal scarring was present in 6.7% (62/921) and 7.6% (69/906) of affected right and left eyes, respectively.

Conclusions: The five-year clinic-based period proportion of attendees with recorded KC was 6.66%. Exploratory adjusted analysis suggested that recorded KC is associated with age, sex, nationality, and location. These findings provide clinic-based epidemiological data on KC in the UAE but should not be interpreted as population prevalence.

KEYWORDS

keratoconus; clinic-based proportion; demography; corneal topography; epidemiology; United Arab Emirates

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How to cite this article: Attaallah S, Aljarousha M, Atallah B. Five-year clinic-based period proportion, demographic profile, and clinical characteristics of recorded keratoconus at tertiary eye centers. *Med Hypothesis Discov Innov Ophthalmol.* 2026; 15(3):198-211. <https://doi.org/10.51329/mehdiophthal1550>

Received: 30 July 2026; Accepted: 25 August 2026



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INTRODUCTION

Keratoconus (KC) is a bilateral, usually asymmetric corneal ectatic disorder characterized by progressive corneal thinning, irregular astigmatism, and visual impairment [1, 2]. It typically develops during adolescence or early adulthood and may continue to progress into the third or fourth decade of life [2, 3]. Younger age is associated with a greater likelihood of progression; a systematic review and meta-analysis by Ferdi et al. [4] reported greater corneal steepening among younger patients. KC can substantially impair vision-related quality of life, affecting visual function and emotional and social well-being [5].

The etiology of KC remains incompletely understood, with both genetic and environmental factors thought to influence disease susceptibility [2, 3]. Eye rubbing is among the behavioral factors most frequently associated with KC [6, 7]. Strong associations have been reported between KC and eye rubbing, particularly rubbing with the knuckles or fingertips [7], while eye rubbing and consanguinity have been identified as significant factors in a multivariable analysis [8]. Genomic and familial studies further support a role for inherited susceptibility, although no single genetic mechanism accounts for all cases [3]. Inflammatory mechanisms have also received increasing attention, with studies reporting higher levels of several inflammatory mediators in keratoconic corneas than in healthy controls [9, 10]. These findings support the multifactorial nature of KC.

Early recognition of KC is clinically important because corneal changes may be subtle during the initial stages of the disease. Corneal topography remains an important diagnostic tool, while pachymetry, tomography, and other corneal measurements provide complementary information, particularly in early or subclinical cases in which no single diagnostic parameter may be sufficient [11, 12]. Systems for describing KC severity have been developed, with the Amsler-Krumeich classification widely recognized for clinical staging that categorizes KC into four stages based on keratometric, refractive, pachymetric, and corneal-scarring criteria [13]. More recent tomography-based systems, such as the ABCD classification, incorporate additional information from the anterior and posterior corneal surfaces [14].

Reported prevalence estimates for KC vary considerably across studies. A pooled global prevalence of 1.38 per 1000 population (0.138%) has been reported, with substantial variation identified between populations [15]. A more recent systematic review and meta-analysis reported a pooled global prevalence of 289.1 per 100,000 persons, with marked geographic variation and considerably higher estimates in West and South Asia [16]. This heterogeneity may reflect differences in the populations studied, geographic and genetic factors, environmental exposures, diagnostic criteria, and KC detection methods [2, 15, 16]. Such methodological differences are particularly important when comparing population-based studies with screening studies or investigations conducted in selected clinical populations.

Relatively high estimates of KC occurrence have been documented in several Middle Eastern populations, though study settings and populations vary substantially. KC was identified in 3.49% of screened young adults in Oman [17], in 2.75% of a predominantly young study population in Saudi Arabia [18], in 4.79% of participants aged 6–21 in Riyadh [19], in 1.5% of tertiary students in Palestine [20], and in 3.3% of Lebanese medical students [21]. Considerably higher estimates are reported among refractive-surgery candidate populations: 8.59% in Taif (Saudi Arabia) [22], 18.19% in Syria [23], and 10.7% in Egypt [24]. These estimates are not directly comparable because the studies differed in participant age, sampling methods, clinical settings, and approaches to KC detection.

Evidence from the United Arab Emirates (UAE) remains limited. Armstrong et al. [25] conducted tomography-based screening among predominantly Emirati secondary-school students in Abu Dhabi, reporting a KC prevalence of 2.7%. Although that study provides important local epidemiological evidence, its adolescent, school-based population differs substantially from patients attending tertiary ophthalmic centers. Consequently, evidence describing recorded KC in larger, multicenter ophthalmic populations in the UAE remains limited, particularly across different age groups and demographic characteristics.

Characterizing the occurrence and clinical features of KC within ophthalmic practice can help quantify the disease burden encountered by eye-care services and identify patterns requiring further investigation [16]. Accordingly, this study aimed to estimate the five-year clinic-based period proportion of attendees with a recorded KC diagnosis across three tertiary ophthalmic centers in Abu Dhabi, Al Ain, and Dubai and to examine associations between recorded KC diagnosis and age, sex, nationality, and location. The study also described laterality, distribution of study-specific composite severity categories, keratometric and pachymetric characteristics, and corneal scarring among affected eyes.

METHODS

This retrospective cross-sectional study used electronic medical records (EMRs) from patients aged ≥ 10 years at their first eligible encounter who attended Magrabi Health Eye Centers in Abu Dhabi, Al Ain, or Dubai, UAE, between

January 2020 and December 2024. A census approach was adopted; all eligible unique clinic attendees within the predefined study period were included after deduplication and application of the eligibility criteria. The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Abu Dhabi Health Research and Technology Committee (ADHRTC), Department of Health (DOH), UAE, before research data extraction and analysis. The approved protocol covered all three participating locations. The ethics committee waived the requirement for informed consent because of the retrospective study design. Permission to access EMRs was also obtained from the Regional Director and Research Department of Magrabi Health. The principal investigator accessed identifiable EMRs solely for data extraction, eligibility verification, and deduplication. Direct patient identifiers, including names and medical record numbers, were removed before statistical analysis, and no study-specific re-identification key or linkage file was created or retained. The resulting analytical dataset was therefore de-identified and contained no direct patient identifiers. It was stored on a secure, password-protected hospital computer in the UAE and was accessible only to the principal investigator. The data were neither transferred nor accessed outside the UAE and are retained and securely disposed of in accordance with institutional and regulatory requirements.

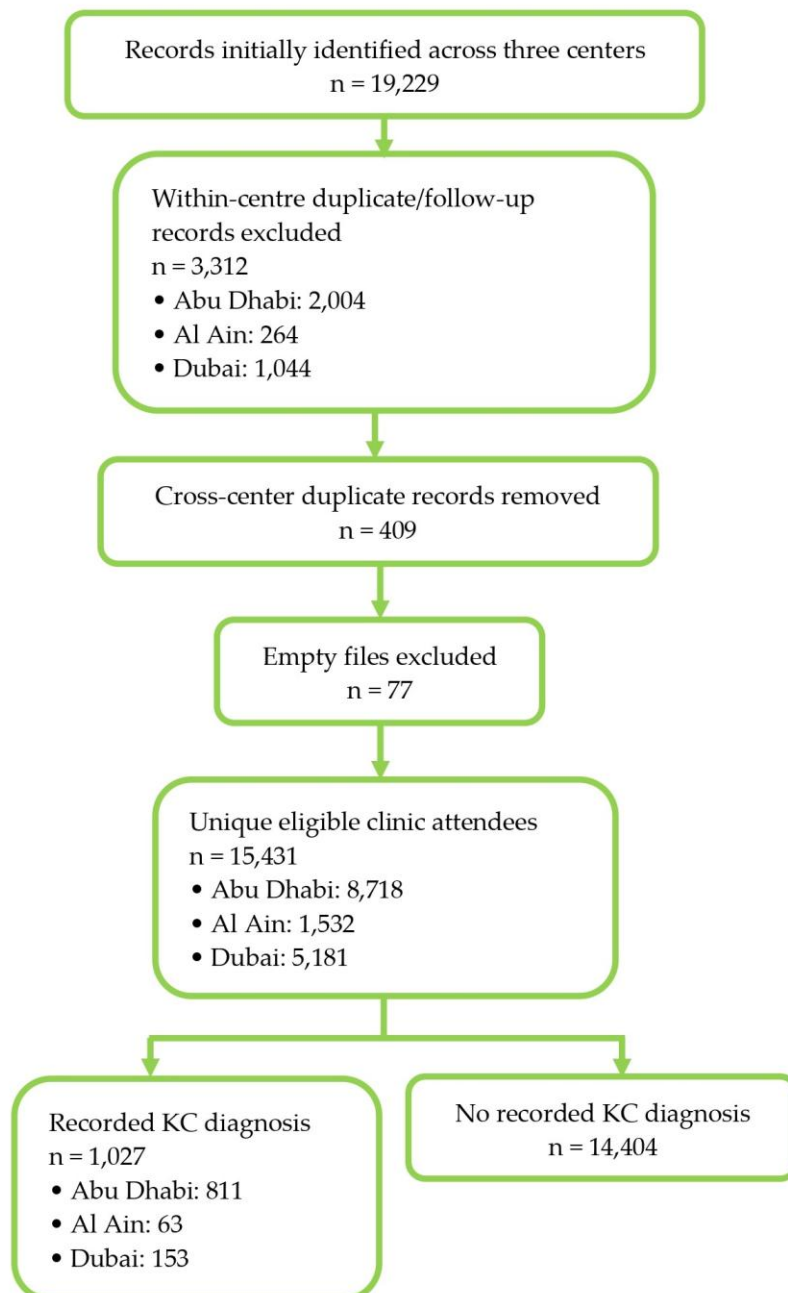


Figure 1. Flow diagram of record identification, deduplication, participant selection, and case ascertainment. Abbreviations: n, numbers of individuals; KC, keratoconus.

Patients aged ≥ 10 years at their first eligible encounter who attended a participating Magrabi Health Eye Centre between January 2020 and December 2024 were eligible for inclusion in the clinic-attendee denominator. Duplicate records and empty files were excluded. Records with incomplete clinical information were retained if eligibility and KC diagnosis status could be determined. Patients with at least one qualifying keratoconus diagnosis code from the prespecified ICD-10-CM code set were classified as KC cases. For the eye-specific analyses, prior corneal surgery was defined as prior corneal transplantation or refractive surgery. Previous corneal cross-linking was not an eye-level exclusion criterion. Only KC-affected eyes were included in the clinical analyses. Clinically unaffected fellow eyes, including those with other corneal conditions or prior disqualifying corneal surgery as defined above, were excluded. Patients with KC in one eye and disqualifying corneal surgery or other ocular pathology in the fellow eye remained in the KC cohort, and the affected KC eye was included where appropriate. No KC-affected eye met the specified eye-level exclusion criteria for other corneal conditions or disqualifying corneal surgery. Missing clinical data did not result in exclusion from the overall clinic-attendee denominator or KC cohort when eligibility and KC diagnosis status could be established.

The study population comprised patients aged ≥ 10 years at their first eligible encounter who attended Magrabi Health Eye Centers in Abu Dhabi, Al Ain, or Dubai between January 2020 and December 2024. Initially, 19,229 records were identified across the three participating locations. Within-center duplicates were identified using medical record numbers (MRNs), enabling repeated visits and follow-up encounters for the same patient to be consolidated into a single record. This process removed 3,312 within-center duplicate records: 2,004 from Abu Dhabi, 264 from Al Ain, and 1,044 from Dubai.

Cross-center deduplication was performed using deterministic exact matching rather than probabilistic record linkage. Potential duplicates across the three locations were initially identified by exact agreement in full name, date of birth, sex, and nationality. Candidate matches were then manually reviewed against the corresponding patient records to verify these identifiers. When demographic identifiers conflicted, the Emirates ID (EID) was checked to confirm patient identity before a record was classified as a duplicate. For confirmed cross-center duplicates, the record containing the most complete clinical and demographic information was retained. This process removed 409 confirmed cross-center duplicate records. An additional 77 empty files containing no usable patient information were excluded. The final clinic-attendee denominator therefore comprised 15,431 unique eligible attendees: 8,718 from Abu Dhabi, 1,532 from Al Ain, and 5,181 from Dubai. [Figure 1](#) presents the process of record identification, deduplication, participant selection, and case ascertainment.

Patients with a recorded KC diagnosis were identified from the EMRs using the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM). Case extraction used a prespecified list of individual keratoconus diagnosis codes within the H18.6 category. The 2015 version of ICD-10-CM was used at all three participating locations throughout the study period [26]. The complete set of codes eligible for capture comprised H18.6, H18.60, H18.61, H18.62, H18.601, H18.602, H18.603, H18.609, H18.611, H18.612, H18.613, H18.619, H18.621, H18.622, H18.623, and H18.629. The distinct codes present among the 1,027 included KC cases were H18.601, H18.602, H18.61, H18.611, H18.612, H18.613, H18.62, H18.621, and H18.622. The same IT team applied the same ICD-10-CM coding system and extraction procedure across the Abu Dhabi, Al Ain, and Dubai locations throughout the study period. Similar ICD-based approaches have been used to identify KC cases in previous large epidemiological studies [27, 28].

Records identified through the diagnostic codes were manually reviewed by the principal investigator. Cases were confirmed using the treating ophthalmologist's documented diagnosis together with available corneal topography, tomography, or both, consistent with established diagnostic principles for KC [29]. Corneal imaging was performed using the Galilei G4 Dual Scheimpflug and Placido imaging system (Ziemer Ophthalmic Systems AG, Port, Switzerland) at the Abu Dhabi location and the Pentacam HR (OCULUS Optikgeräte GmbH, Wetzlar, Germany) at the Al Ain and Dubai locations. Imaging findings supported confirmation of the recorded diagnosis and were used for clinical characterization and severity categorization; they were not applied as independent threshold-based case-ascertainment criteria. Patients documented only as KC suspects or as having subclinical KC without a confirmed KC diagnosis were not classified as KC cases but remained in the overall clinic-attendee denominator. Records without a KC diagnostic code were not individually reviewed for potentially missed cases. Device software versions and specific imaging-quality criteria were not consistently documented in the retrospective records and therefore could not be reliably standardized or reported. A total of 1,027 patients with recorded KC were identified; 811 from Abu Dhabi, 63 from Al Ain, and 153 from Dubai. For the primary estimate, the numerator comprised these 1,027 eligible patients, each with at least one

recorded KC diagnosis code captured by the prespecified ICD-10-CM code set described above. The denominator comprised all 15,431 unique eligible patients aged ≥ 10 years at their first eligible encounter who attended the three participating centers during the study period. The resulting estimate represents the five-year clinic-based period proportion of attendees with a recorded KC diagnosis. Because universal systematic screening for KC was not performed among all clinic attendees, this estimate should not be interpreted as the prevalence of KC in the general UAE population.

All eligible records meeting the study criteria during the study period were included. Accordingly, convenience sampling was not used, and no formal sample-size or power calculation was required.

For patients with a recorded KC diagnosis, the corresponding EMRs were reviewed for available demographic and clinical characteristics. Age was calculated from each attendee's date of birth at the first eligible encounter during the study period (1 January 2020 to 31 December 2024). The same index-date definition was applied to attendees with and without a recorded KC diagnosis. Age was subsequently categorized as ≤ 20 , 21–30, 31–40, 41–50, 51–60, or > 60 years for subgroup and regression analyses. For patients with multiple encounters, laterality, keratometry, pachymetry, refractive error, corneal scarring, and study-specific composite severity category were determined from the most recent available KC examination documented in the EMR. Sex and nationality were obtained from the corresponding demographic fields. KC diagnosis status was based on the presence of at least one qualifying keratoconus diagnosis code from the prespecified ICD-10-CM code set at any time during the study period.

Eye-specific clinical analyses included only KC-affected eyes. Clinically unaffected fellow eyes, including those with other corneal conditions or previous disqualifying corneal surgery as defined in the inclusion and exclusion criteria, were excluded. Previous corneal cross-linking was not an exclusion criterion. No KC-affected eye met the specified eye-level exclusion criteria for other corneal conditions or disqualifying corneal surgery. Accordingly, all 921 affected right eyes and 906 affected left eyes were included in the eye-specific analyses. Mean keratometry (Kmean) was calculated separately for each affected eye as the average of the flat (K1) and steep (K2) keratometric readings.

The principal investigator retrospectively applied a study-specific composite severity classification to each affected eye using available keratometric, refractive, minimum corneal thickness, and corneal-scarring data. The classification was informed by selected components of the Amsler–Krumeich and Belin ABCD systems [13, 14, 30, 31] but was operationalized specifically for this retrospective study and should not be regarded as equivalent to either conventional system. Keratometric severity was classified as Category I for Kmean < 48.00 D, Category II for Kmean ≥ 48.00 to < 53.00 D, Category III for Kmean ≥ 53.00 to ≤ 55.00 D, and Category IV for Kmean > 55.00 D.

Refractive severity was determined from the manifest subjective refraction documented at the most recent KC examination. For each affected eye, refractive magnitude was operationalized as the sum of the absolute magnitudes of the myopic spherical and cylindrical components of the subjective refraction. Sphere and cylinder were not categorized separately; their absolute magnitudes were summed to produce a single refractive magnitude used for severity categorization. Refractive severity was classified as Category I for values < 5.00 D, Category II for values ≥ 5.00 to < 8.00 D, and Category III for values ≥ 8.00 to ≤ 10.00 D. Values equal to 10.00 D were assigned to Category III; however, no affected eye had a recorded refractive magnitude of exactly 10.00 D. Refractive values > 10.00 D did not independently determine Category IV. Eyes with Kmean > 55.00 D were assigned Category IV according to the keratometric criterion, irrespective of refractive value. For eyes with refractive values > 10.00 D and Kmean ≤ 55.00 D, the refractive value did not independently increase the severity category. Instead, the final category was determined by the most advanced applicable category supported by the remaining keratometric, pachymetric, and corneal-scarring criteria. This combination occurred in 10 affected right eyes and no affected left eyes. Refraction specifically documented as unmeasurable because of advanced KC was considered a Category IV criterion.

For the pachymetric component, minimum corneal thickness ≥ 300 to < 400 μm was classified as Category III and < 300 μm as Category IV; values ≥ 400 μm did not independently increase the severity category. Corneal scarring was classified as a Category IV criterion. When the component criteria indicated different categories, the final category was assigned according to the most advanced applicable criterion supported by the available clinical data. This study-specific composite classification has not been independently validated, and its categories are not directly comparable with conventional Amsler–Krumeich stages or complete Belin ABCD grades.

Measurable refractive data were available for 859 of 921 affected right eyes and 837 of 906 affected left eyes. Refraction was specifically documented as unmeasurable in 62 right eyes and 69 left eyes because advanced keratoconus with corneal scarring precluded reliable refractive measurement. These counts therefore correspond to the same eyes in

which corneal scarring was recorded. No affected eye had missing or undocumented refractive data. Missing or undocumented refraction was not treated as unmeasurable because of advanced KC; however, because no such observations occurred, no additional procedure for categorizing missing refractive data was required.

Available keratometric, refractive, and pachymetric measurements documented in the EMRs were used. Previous corneal cross-linking status and contact-lens discontinuation before imaging were not consistently documented. Consequently, measurements could not be uniformly classified as having been obtained before or after cross-linking, and contact-lens discontinuation could not be standardized retrospectively. Specific imaging-quality criteria were not consistently documented either so they couldn't be standardized retrospectively. Blank cells, dashes (–), and “NA” entries in the source dataset represented observations that were not applicable to the KC eye-specific analyses—including records from non-KC patients and fellow eyes that were unaffected by KC, had other corneal conditions, or had undergone previous corneal surgery. These entries were not treated as missing data. Among the 921 affected right eyes and 906 affected left eyes included in the eye-specific KC analyses, complete data were available for K1, K2, minimum corneal thickness (MCT), study-specific composite severity category, and corneal scarring. Refractive-data availability and its handling in the severity categorization are described above.

Data were analyzed using IBM SPSS Statistics, version 32.0 (IBM Corp., Armonk, NY, USA). Normality of continuous-variable distributions was assessed using the Shapiro–Wilk and Kolmogorov–Smirnov tests. Because both tests indicated significant departures from normality ($P < 0.001$), continuous variables were summarized using medians and interquartile ranges (IQRs). Categorical variables were presented as frequencies and percentages. The five-year clinic-based period proportion of attendees with a recorded KC diagnosis was calculated by dividing the number of unique attendees with recorded KC by the total number of unique eligible attendees. The overall clinic-based period proportion and subgroup-specific proportions were calculated and reported with Wilson 95% confidence intervals (CIs). Pearson's chi-square test was used to assess associations between recorded KC diagnosis and age group, sex, nationality, and location. Cramer's V was used to quantify the strength of these associations. Exploratory multivariable binary logistic regression was used to assess the adjusted associations of age group, sex, nationality, and location with recorded KC diagnosis. The reference categories were age ≤ 20 years, female sex, Emirati nationality, and Abu Dhabi. All variables were entered simultaneously, and adjusted odds ratios (aORs) with 95% CIs were reported. No data were missing for age group, sex, nationality, or location, therefore complete-case exclusion for these covariates was unnecessary. Calendar period was not included as a covariate in the primary multivariable model, which was prespecified to examine demographic and center-level associations with recorded KC diagnosis. Overall model significance was assessed using the omnibus likelihood-ratio chi-square test, and calibration was evaluated using the Hosmer–Lemeshow test. Because this was an exploratory observational analysis, the aORs were interpreted as adjusted associations rather than definitive evidence of independent effects. Statistical significance was set at $P < 0.05$.

RESULTS

The study population included 15,431 unique eligible clinic attendees, 8,967 (58.1%) male and 6,464 (41.9%) female. There were 8,388 (54.4%) Emirati attendees and 7,043 (45.6%) non-Emirati. The largest age group comprised attendees aged ≤ 20 years (2,918; 18.9%), followed by those aged 31–40 (2,750; 17.8%) and 21–30 (2,723; 17.6%). There were 2,449 (15.9%) attendees aged 41–50, 2,385 (15.5%) aged 51–60, and 2,206 (14.3%) aged > 60 . [Table 1](#) presents the demographic characteristics of the study population.

Among the 15,431 unique eligible clinic attendees across the three participating locations during the five-year study period, 1,027 had a recorded KC diagnosis, corresponding to a clinic-based period proportion of 6.66% (95% CI, 6.27% to 7.06%). The remaining 14,404 attendees (93.34%) had no recorded KC diagnosis ([Table 2](#)).

The proportion of attendees with a recorded KC diagnosis differed significantly across age groups ($\chi^2(5) = 754.24$, $P < 0.001$; Cramer's V = 0.221). The highest age-specific proportion was observed among attendees aged 21–30 (14.07%), followed by those aged 31–40 (13.49%). The proportion was also significantly higher among males than females (7.75% versus 5.14%; $\chi^2(1) = 41.33$, $P < 0.001$; Cramer's V = 0.052) and among non-Emirati than Emirati attendees (8.95% versus 4.73%; $\chi^2(1) = 109.33$, $P < 0.001$; Cramer's V = 0.084). The proportion differed significantly by location ($\chi^2(2) = 228.60$, $P < 0.001$; Cramer's V = 0.122) and was highest in Abu Dhabi (9.30%), followed by Al Ain (4.11%) and Dubai (2.95%) ([Table 3](#)).

Table 1. Demographic characteristics of the study population (N = 15,431)

Variable	Value
Age group (y), n (%)	
≤ 20	2,918 (18.9)
21–30	2,723 (17.6)
31–40	2,750 (17.8)
41–50	2,449 (15.9)
51–60	2,385 (15.5)
> 60	2,206 (14.3)
Sex (Male / Female), n (%)	8,967 (58.1) / 6,464 (41.9)
Nationality (Emirati / Non-Emirati), n (%)	8,388 (54.4) / 7,043 (45.6)
Center Location (Abu Dhabi / Al Ain / Dubai), n (%)	8,718 (56.5) / 1,532 (9.9) / 5,181 (33.6)

Abbreviations: y, years; n, number of individuals; %, percentage.

Table 2. Five-year clinic-based period proportion of attendees with a recorded keratoconus diagnosis (N = 15,431)

Recorded KC Diagnosis	n (%)	Wilson 95% CI
Yes	1,027 (6.66)	6.27–7.06
No	14,404 (93.34)	-
Total	15,431 (100.0)	-

Abbreviations: KC, keratoconus; n, number of individuals; %, percentage; CI, confidence interval.

Table 3. Demographic characteristics and proportions with recorded keratoconus diagnosis among clinic attendees

Characteristic	Total, n	Recorded KC, n (%) ¹	Wilson 95% CI	χ^2 (df)	P-value	Cramer's V
Age group (y)				754.24 (5)	< 0.001	0.221
≤ 20	2,918	117 (4.01)	3.36–4.78			
21–30	2,723	383 (14.07)	12.81–15.42			
31–40	2,750	371 (13.49)	12.26–14.82			
41–50	2,449	124 (5.06)	4.26–6.00			
51–60	2,385	27 (1.13)	0.78–1.64			
> 60	2,206	5 (0.23)	0.10–0.53			
Sex				41.33 (1)	< 0.001	0.052
Female	6,464	332 (5.14)	4.62–5.70			
Male	8,967	695 (7.75)	7.22–8.32			
Nationality				109.33 (1)	< 0.001	0.084
Emirati	8,388	397 (4.73)	4.30–5.21			
Non-Emirati	7,043	630 (8.95)	8.30–9.63			
Center Location				228.60 (2)	< 0.001	0.122
Abu Dhabi	8,718	811 (9.30)	8.71–9.93			
Al Ain	1,532	63 (4.11)	3.23–5.23			
Dubai	5,181	153 (2.95)	2.53–3.45			

Abbreviations: n, number of individuals; KC, keratoconus; CI, confidence interval; df, degrees of freedom; χ^2 , chi-square statistic. Note: Boldface indicates P -value < 0.05; ¹Percentages represent the proportion of attendees within each demographic category with a recorded KC diagnosis; CIs were calculated using the Wilson score method; χ^2 values represent Pearson chi-square statistics; df are shown in parentheses.

Among the 1,027 patients with a recorded KC diagnosis, 800 (77.9%) had bilateral involvement, 121 (11.8%) had right-eye-only involvement, and 106 (10.3%) had left-eye-only involvement. Accordingly, 921 right eyes and 906 left eyes were affected by KC. No KC-affected eye met the specified eye-level exclusion criteria, therefore all 921 affected right eyes and 906 affected left eyes were included in the eye-specific analyses. Complete data for K1, K2, MCT, study-specific composite severity category, and corneal scarring were available for all affected eyes (OD, 921/921; OS, 906/906), with no missing observations for these variables. Measurable refractive data were available for 859/921 affected right eyes and 837/906 affected left eyes. Refraction was unmeasurable in 62 right eyes and 69 left eyes because of advanced keratoconus with corneal scarring; these were the same eyes reported as having corneal scarring. No affected right or left eye had missing or undocumented refractive data.

Category I was the most frequent study-specific composite severity category in both affected right eyes (499/921; 54.2%) and affected left eyes (515/906; 56.8%). Category II comprised 229 (24.9%) right eyes and 210 (23.2%) left eyes; category III comprised 115 (12.5%) and 96 (10.6%), respectively; and category IV comprised 78 (8.5%) and 85 (9.4%), respectively. Corneal scarring was documented in 62/921 right eyes (6.7%) and 69/906 left eyes (7.6%).

Table 4. Clinical characteristics of patients with recorded keratoconus

Characteristic	Values
Affected Eyes (OD / OS), n	921 / 906
Laterality (n = 1,027), n (%)	
OD / OS / OU	121 (11.8) / 106 (10.3) / 800 (77.9)
Keratometry — OD, Median (IQR)	
K1 (D) (n = 921)	44.75 (43.00–47.00)
K2 (D) (n = 921)	47.50 (45.25–51.00)
Kmean (D) (n = 921)	46.13 (44.25–49.13)
Keratometry — OS, Median (IQR)	
K1 (D) (n = 906)	44.75 (43.00–47.00)
K2 (D) (n = 906)	47.25 (45.25–50.50)
Kmean (D) (n = 906)	45.94 (44.13–48.63)
Minimum Corneal Thickness, Median (IQR)	
MCT OD (µm) (n = 921)	466.00 (432.00–495.00)
MCT OS (µm) (n = 906)	465.00 (426.00–495.00)
Corneal Scarring — OD, n (%)	
Yes / No	62 (6.7) / 859 (93.3)
Corneal Scarring — OS, n (%)	
Yes / No	69 (7.6) / 837 (92.4)
Study-specific composite severity category — OD (n = 921), n (%)	
Category I	499 (54.2)
Category II	229 (24.9)
Category III	115 (12.5)
Category IV	78 (8.5)
Study-specific composite severity category — OS (n = 906), n (%)	
Category I	515 (56.8)
Category II	210 (23.2)
Category III	96 (10.6)
Category IV	85 (9.4)

Abbreviations: D, diopters; IQR, interquartile range; K1, flat keratometric reading; K2, steep keratometric reading; KC, keratoconus; MCT, minimum corneal thickness; n, number of individuals; NA, not applicable; OD, right eye; OS, left eye; OU, both eyes; µm, micrometers. Note: Severity was categorized using the study-specific composite algorithm described in the Methods section. The algorithm combined selected keratometric, refractive, pachymetric, and corneal-scarring criteria informed by the conventional Amsler–Krumeich and Belin ABCD systems but was not equivalent to either classification system. Complete data for K1, K2, MCT, study-specific composite severity category, and corneal scarring were available for all affected eyes included in the eye-specific analyses (OD, n = 921; OS, n = 906). Measurable refractive data were available for 859/921 affected right eyes and 837/906 affected left eyes. In the remaining 62 right eyes and 69 left eyes, advanced keratoconus with corneal scarring precluded reliable refractive measurement; these were the same eyes recorded as having corneal scarring. The resulting categories should not be compared directly with conventional Amsler–Krumeich stages or complete Belin ABCD grades. Blank cells, dashes (–), and “NA” entries in the source dataset denoted observations that were not applicable to the KC eye-specific analyses and were not treated as missing data. No KC-affected eye was excluded from the eye-specific analyses because of another corneal condition or previous disqualifying corneal surgery. Previous corneal cross-linking was not an exclusion criterion.

Table 5. Univariable and exploratory multivariable logistic regression analyses of factors associated with recorded keratoconus diagnosis

Variable	Crude OR	95% CI	P-value	aOR	95% CI	P-value
Age group, years			< 0.001			< 0.001
≤20	1.00 (reference)	-	-	1.00 (reference)	-	-
21–30	3.92	3.16–4.85	< 0.001	4.15	3.34–5.15	< 0.001
31–40	3.73	3.01–4.63	< 0.001	3.85	3.10–4.79	< 0.001
41–50	1.28	0.99–1.65	0.064	1.30	1.01–1.69	0.048
51–60	0.27	0.18–0.42	< 0.001	0.28	0.19–0.43	< 0.001
>60	0.05	0.02–0.13	< 0.001	0.05	0.02–0.12	< 0.001
Sex			< 0.001			
Female	1.00 (reference)	-	-	1.00 (reference)	-	-
Male	1.55	1.36–1.78	< 0.001	1.62	1.40–1.86	< 0.001
Nationality			< 0.001			
Emirati	1.00 (reference)	-	-	1.00 (reference)	-	-
Non-Emirati	1.98	1.74–2.25	< 0.001	1.86	1.63–2.13	< 0.001
Centre location			< 0.001			
Abu Dhabi	1.00 (reference)	-	-	1.00 (reference)	-	-
Al Ain	0.42	0.32–0.54	< 0.001	0.46	0.35–0.60	< 0.001
Dubai	0.30	0.25–0.35	< 0.001	0.28	0.23–0.34	< 0.001

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; OR, odds ratio. Note: Crude ORs were obtained from separate univariable binary logistic regression models; aORs were obtained from a multivariable binary logistic regression model that included age group, sex, nationality, and location simultaneously. Reference categories were age ≤ 20 years, female sex, Emirati nationality, and Abu Dhabi. The overall multivariable model was statistically significant ($\chi^2(9) = 1\,234.15$, $P < 0.001$; Nagelkerke $R^2 = 0.199$). The Hosmer–Lemeshow test was not statistically significant ($\chi^2(8) = 8.30$, $P = 0.405$). Because the multivariable analysis was exploratory, the aORs should be interpreted cautiously as exploratory estimates of association.

Median K1 was 44.75 D (IQR, 43.00–47.00) in both right and left eyes. Median K2 was 47.50 D (IQR, 45.25–51.00) in the right eye and 47.25 D (IQR, 45.25–50.50) in the left eye. Median Kmean was 46.13 D (IQR, 44.25–49.13) in the right eye and 45.94 D (IQR, 44.13–48.63) in the left eye. Median MCT was 466 μm (IQR, 432–495) in the right eye and 465 μm (IQR, 426–495) in the left eye (Table 4).

In the exploratory multivariable logistic regression analysis, age group, sex, nationality, and location were associated with recorded KC diagnosis after mutual adjustment. Compared with attendees aged ≤ 20 years, the 21–30 age group had the highest adjusted odds of recorded KC (aOR = 4.15; 95% CI, 3.34 to 5.15; $P < 0.001$), followed by the 31–40 age group (aOR = 3.85; 95% CI, 3.10 to 4.79; $P < 0.001$). Attendees aged 41–50 years also had higher adjusted odds (aOR = 1.30; 95% CI, 1.01 to 1.69; $P < 0.05$), whereas the 51–60 age group (aOR = 0.28; 95% CI, 0.19 to 0.43; $P < 0.001$) and > 60 age group (aOR = 0.05; 95% CI, 0.02 to 0.12; $P < 0.001$) had lower adjusted odds.

Male attendees had higher adjusted odds than females (aOR = 1.62; 95% CI, 1.40 to 1.86; $P < 0.001$), and non-Emirati attendees had higher adjusted odds than Emiratis (aOR = 1.86; 95% CI, 1.63 to 2.13; $P < 0.001$). Compared with attendees in Abu Dhabi, those in Al Ain (aOR = 0.46; 95% CI, 0.35 to 0.60; $P < 0.001$) and Dubai (aOR = 0.28; 95% CI, 0.23 to 0.34; $P < 0.001$) had lower adjusted odds of recorded KC (Table 5).

The overall model was statistically significant ($\chi^2(9) = 1\,234.15$, $P < 0.001$), with a Nagelkerke R^2 of 0.199. The Hosmer–Lemeshow goodness-of-fit test was not statistically significant ($\chi^2(8) = 8.30$, $P = 0.405$), indicating no evidence of lack of fit based on this test.

DISCUSSION

This multicenter retrospective study found that 6.66% of 15,431 unique eligible attendees at three tertiary ophthalmic centers in Abu Dhabi, Al Ain, and Dubai had a recorded KC diagnosis during the five-year study period. This estimate represents a clinic-based period proportion of recorded KC rather than population prevalence because attendees were not systematically screened and case ascertainment relied on diagnoses documented in the EMRs. The findings should therefore be interpreted within the context of a specialized ophthalmic population, in which referral patterns, refractive-surgery assessment, corneal evaluation, and the underlying case mix are likely to differ from those in the general UAE population.

The observed proportion is numerically higher than estimates derived from general-population or screening studies but falls within the broad range reported from selected ophthalmic populations in the Middle East. Armstrong et al. [25] reported a KC prevalence of 2.7% using systematic corneal tomography in predominantly Emirati secondary-school

students in Abu Dhabi, while Al Saidi et al. [17] identified KC in 3.49% of screened young adults in Oman. Similarly, Torres Netto et al. [19] reported a prevalence of 4.79% among participants aged 6–21 in Riyadh using systematic Scheimpflug tomography. Student-screening studies have likewise reported estimates of 1.5% in Palestine [20], 3.3% in Lebanon [21], and 3.18% in Israel [32]. By contrast, considerably higher estimates have been reported among refractive-surgery candidates, including 8.59% in Taif (Saudi Arabia) [22], 18.19% in Syria [23], and 10.7% in Assiut (Egypt) [24]. These differences demonstrate why prevalence estimates from population screening, student cohorts, refractive-surgery candidates, and tertiary eye clinics should not be interpreted as directly equivalent. Althomali et al. [22] specifically acknowledged that their highly selected refractive-surgery population would be expected to produce a higher estimate than population-based studies, while Salman et al. [23] noted that reported prevalence varies according to the diagnostic criteria and cohort examined.

The adjusted demographic findings discussed below should be interpreted as exploratory because the multivariable analysis was designed to examine adjusted associations rather than establish causal relationships. Age showed one of the strongest associations in the present study. The proportion of attendees with recorded KC was highest among the 21–30 age group, followed closely by the 31–40 age group; both cohorts had markedly higher adjusted odds than attendees aged ≤ 20 years. This concentration in younger adulthood is consistent with the established epidemiology and natural history of KC, although the precise age distribution varies by study design and case-ascertainment methods. In a nationwide Dutch study of approximately 4.4 million individuals, Godefrøij et al. [33] reported a mean age at diagnosis of 28.3 years. More recently, a global meta-analysis by Sriranganathan et al. [16] found that adults aged 20–29 had the highest pooled prevalence and incidence of KC. Clinical evidence also indicates that KC is more frequently observed among younger adults; for example, the largest age group in the tertiary keratoconus-center cohort examined by Flockerzi et al. [34] was 21–30 years. Hence the age distribution observed in the present study broadly concords with previous epidemiological and clinical evidence. However, because age was determined at the first eligible encounter and KC ascertainment was based on recorded rather than incident diagnoses, these findings should not be interpreted as indicating age at KC onset or diagnosis. Younger age nevertheless remains clinically relevant because natural-history evidence indicates greater disease progression among younger patients [4].

In the exploratory adjusted analysis, male sex was associated with higher odds of recorded KC. This finding is consistent with several large epidemiological studies, although sex differences have not been uniformly observed across the literature [35]. Godefrøij et al. [33] reported that 60.6% of patients diagnosed with KC were male, while the recent global meta-analysis by Sriranganathan et al. [16] found higher odds of KC among males than females. In a case-control analysis, Moran et al. [7] also identified male sex as independently associated with KC. By contrast, several regional studies have found no statistically significant sex differences. Althomali et al. [22] reported no significant difference between male and female refractive-surgery candidates, while Shneor et al. [32] observed a numerically higher prevalence among males that did not reach statistical significance. The present findings therefore add to evidence of male predominance in some KC populations; however, the underlying explanation remains uncertain and may involve behavioral, environmental, biological, or healthcare-utilization differences [28, 36] that could not be evaluated using this retrospective dataset.

Non-Emirati attendees also had higher adjusted odds of recorded KC than Emiratis. This finding should be interpreted cautiously because nationality is a broad demographic classification and does not directly reflect ethnicity, genetic ancestry, environmental exposure, or socioeconomic background [37–40]. KC susceptibility is considered multifactorial, with both genetic and environmental factors implicated in its development [3]. Family history and consanguinity have also been investigated as potential factors associated with KC. Among young Arab students in Israel, parental first-cousin consanguinity remained significantly associated with KC after multivariable adjustment [32], and similar associations have been reported in other populations [8, 41]. However, as these factors were not consistently measured in the present study, the observed association with nationality should not be interpreted as evidence of a genetic or ethnic effect. Differences in country of origin, occupational or environmental exposures, referral behavior, demographic composition, healthcare access [42–44], and other unmeasured characteristics may have contributed to this association and warrant investigation in appropriately designed population-based studies.

Location-level differences persisted after adjustment for age, sex, and nationality; however, these exploratory estimates should be interpreted cautiously and should not be regarded as evidence of true geographic differences in KC susceptibility [45]. Regional multicenter studies have similarly demonstrated substantial variation between locations. For example, Salman et al. [23] reported KC proportions of 24.22% in Damascus, 13.6% in Latakia, and 17.0% in Tartous

within the same refractive-surgery study. Differences between locations may reflect variation in population composition, referral pathways, access to corneal or refractive assessment, diagnostic practices, and other location-specific factors [43]. Accordingly, the differences observed among Abu Dhabi, Al Ain, and Dubai should be interpreted as location-level associations rather than evidence of geographic causation.

The clinical findings were broadly consistent with the recognized bilateral and asymmetric nature of KC. Bilateral involvement was observed in 77.9% of patients, similarly to the 76.27% reported among manifest KC cases by Althomali et al. [22]; Naderan et al. [46] reported bilateral disease in 88.3% of an Iranian KC population. These findings support the observation that unilateral clinical presentation occurs in a minority of KC cases, although asymmetry between fellow eyes is common. Using the study-specific composite severity classification described in the Methods, Category I was the most frequent one, accounting for 54.2% of affected right eyes and 56.8% of affected left eyes. Corneal scarring was documented in 6.7% and 7.6% of affected right and left eyes, respectively. The predominance of Category I and the relatively low frequency of corneal scarring suggest that advanced changes, as defined by the study-specific composite classification, were comparatively uncommon in this cohort. Because this classification modified selected conventional thresholds, its category distribution should not be compared directly with studies using conventional Amsler–Krumeich staging or complete Belin ABCD grading [13, 14]. Moreover, the retrospective design precluded determination of the timing of KC diagnosis.

These findings have practical implications for KC detection in ophthalmic practice. The higher proportion of recorded KC among younger adults highlights the importance of maintaining clinical awareness beyond adolescence, particularly in patients with changing refraction or increasing or irregular astigmatism [47]. Corneal tomography has facilitated the detection of early and subclinical disease [48], and systematic screening research in Abu Dhabi has demonstrated the feasibility of tomography-based KC screening among adolescents [25]. However, the demographic associations observed in the present study should not be used to define population-screening criteria. Prospective population-based studies are needed to determine the true prevalence of KC in the UAE and establish whether demographic, behavioral, environmental, or familial factors can reliably identify groups that may benefit from targeted screening [49].

The strengths of this study include its large multicenter sample of 15,431 unique attendees across Abu Dhabi, Al Ain, and Dubai, cross-center deduplication, and detailed eye-level characterization of patients with recorded KC. The study also provides exploratory adjusted estimates of demographic associations and clearly distinguishes the overall clinic-attendee denominator from the affected-eye denominators used in clinical analyses. It therefore represents one of the largest multicenter descriptions of recorded KC in UAE ophthalmic practice and provides a foundation for future prospective, population-based epidemiological research.

Several limitations should be considered. Severity was assessed using an independently unvalidated, study-specific composite classification informed by selected conventional Amsler–Krumeich and Belin ABCD criteria [13, 14] rather than either complete system. The resulting categories should therefore be interpreted descriptively and should not be compared directly with severity distributions based on conventional Amsler–Krumeich staging or complete Belin ABCD grading. The retrospective, clinic-based design limits generalizability because patients attending tertiary ophthalmic centers may differ from the wider UAE population. Moreover, KC ascertainment relied on diagnoses recorded in the EMRs rather than systematic screening of all attendees, and records without a KC diagnostic code were not individually reviewed. Undiagnosed, subclinical, unrecorded, uncoded, or unrecognized cases may therefore have been missed. Accordingly, the estimate represents a five-year clinic-based period proportion of attendees with recorded KC rather than population prevalence. Calendar-period heterogeneity was not evaluated, so potential changes in clinic attendance or diagnostic practices during 2020–2024 were not assessed. The multivariable logistic regression was exploratory and limited to the available demographic and location-level variables, leaving the possibility of residual confounding by unmeasured clinical, behavioral, environmental, or familial factors. The model may not have fully captured the relationships between the included covariates and recorded KC diagnosis, hence the adjusted odds ratios should not be interpreted as definitive evidence of independent effects—they require confirmation using appropriately specified and validated models. Routinely collected clinical records may also have introduced variation in diagnostic assessment, imaging, and documentation. Potential KC-related factors, including family history, consanguinity, allergy or atopy, eye rubbing, and environmental exposures, were not consistently documented and could not be evaluated. Nationality should therefore be interpreted only as a demographic characteristic, not as evidence of genetic or ethnic causation. Finally, the cross-sectional design precluded assessment of disease incidence, progression, and longitudinal outcomes.

Future prospective, population-based studies using standardized diagnostic and severity criteria, comprehensive assessment of potential risk factors, and longitudinal follow-up are warranted to address these limitations.

CONCLUSIONS

The five-year clinic-based period proportion of attendees with a recorded KC diagnosis was 6.66%. Exploratory adjusted analysis suggested associations between recorded KC and age, sex, nationality, and location, with attendees aged 21–30 and 31–40 years having the highest adjusted odds compared with those aged ≤ 20 years. These findings apply to the participating tertiary clinic population and should not be interpreted as population prevalence or evidence of population-level risk. Most patients had bilateral disease (77.9%). Category I was the most frequent study-specific composite severity category in affected right (54.2%) and left (56.8%) eyes, while corneal scarring was relatively uncommon. This study provides multicenter, clinic-based epidemiological data on KC in the UAE, and underscores the need for prospective population-based studies using standardized screening and diagnostic protocols.

ETHICAL DECLARATIONS

Ethical approval: The study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Abu Dhabi Health Research and Technology Committee (ADHRTC), Department of Health (DOH), UAE, before research data extraction and analysis. The approved protocol covered all three participating locations. The ethics committee waived the requirement for informed consent because of the retrospective study design. Permission to access EMRs was also obtained from the Regional Director and Research Department of Magrabi Health. The principal investigator accessed identifiable EMRs solely for data extraction, eligibility verification, and deduplication. Direct patient identifiers, including names and medical record numbers, were removed before statistical analysis, and no study-specific re-identification key or linkage file was created or retained. The resulting analytical dataset was therefore de-identified and contained no direct patient identifiers. It was stored on a secure, password-protected hospital computer in the UAE and was accessible only to the principal investigator. The data were neither transferred nor accessed outside the UAE and are retained and securely disposed of in accordance with institutional and regulatory requirements.

Conflict of interest: None.

FUNDING

None.

ACKNOWLEDGMENTS

This study used clinical data from participating Magrabi Health Eye Centres in Abu Dhabi, Al Ain, and Dubai. Following ethical approval, Magrabi Health granted institutional permission to access the clinical records but had no role in the study design, statistical analysis, interpretation of the findings, or decision to submit the manuscript for publication.

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